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THE MIDDLE PALEOZOIC STRATIGRAPHY OF THE CENTRAL ROCKY MOUNTAIN REGION

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PART II

STRATIGRAPHY—*Continued*

UPPER CAMBRIAN AND EARLY ORDOVICIAN

Members o and 1.—Throughout western Wyoming, and at least as far north as Livingston, Montana, the thin-bedded upper part of the Gallatin formation rests upon a very massive cliff-making dolomite (Member 1), ranging up to 400 feet or more in thickness. Near Three Forks this member constitutes the "mottled limestone" (middle division of the Gallatin formation) of Peale,[1] which was correlated by Weed[2] with the Pilgrim limestone of the Little Belt Mountains. It corresponds roughly in position and in general character to the Hasmark formation, which was differentiated by Emmons and Calkins[3] in the Philipsburg quadrangle, Montana, and tentatively correlated by them with the Pilgrim.

Underlying this massive member in Wyoming and Montana is a zone of weaker strata (Member o) in which green shales predominate, interstratified with thin beds of dolomite and flat-pebble limestone conglomerate. This belt includes the "*Obolella* shales" of Peale[4] in the Three Forks quadrangle, and at least the upper part of the Gros Ventre shale of Blackwelder[5] in western Wyoming; and is probably represented in the Park shale of Weed[6] in Montana.

[1] A. C. Peale, "Description of the Three Forks (Montana) Sheet," *Geol. Atlas U.S.*, Folio 24 (1896).

[2] W. H. Weed, "Geology of the Little Belt Mountains, Montana," *U.S. Geol. Survey, 20th Ann. Rept.*, Part 3 (1900), Pl. 40, opp. p. 284; p. 286.

[3] W. H. Emmons and F. C. Calkins, "Geology and Ore Deposits of the Philipsburg Quadrangle, Montana," *U.S. Geol. Survey, Prof. Paper 78* (1913), pp. 57–59, 63.

[4] *Op. cit.* [5] Eliot Blackwelder, unpublished manuscript. [6] *Op. cit.*, p. 286.

The upper part of the Cambrian sequence in Utah is not unlike that in Wyoming. There is a very prominent massive member (No. 1), which is overlain by thin-bedded dolomites (Members

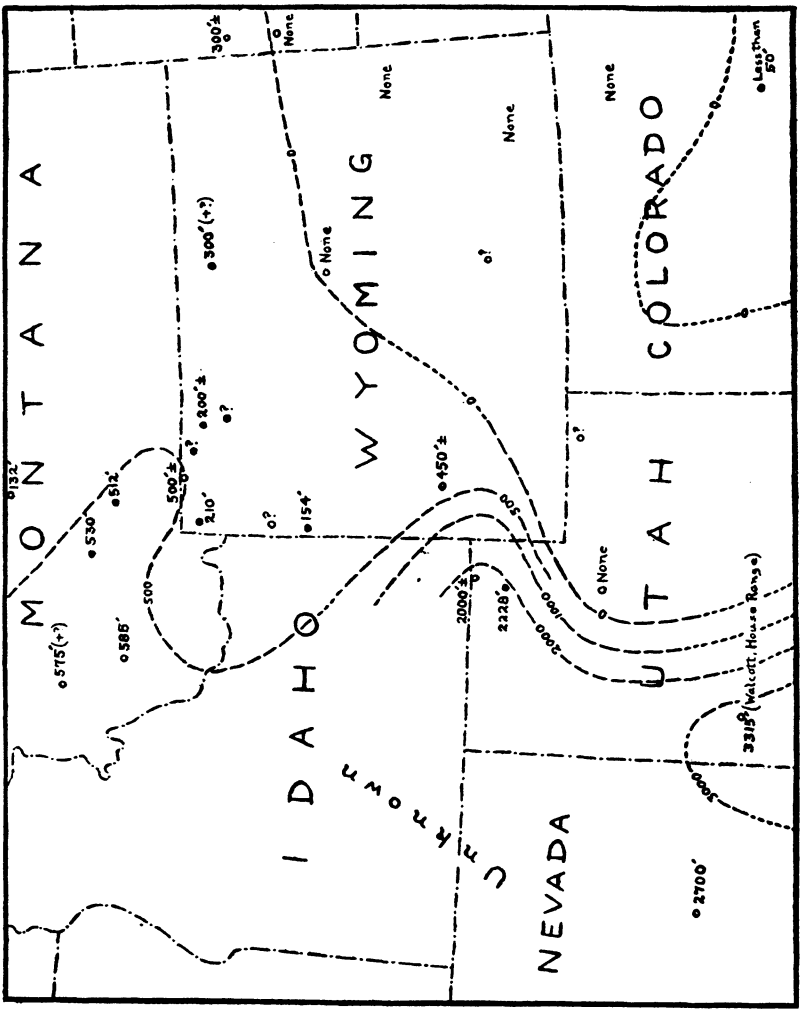

FIG. 6.—Map showing the extent and thickness of the Upper Cambrian and Early Ordovician series (Members 1 to 4, inclusive).

2–4) containing a great deal of flat-pebble limestone conglomerate, and is underlain by a series (Member o) of thin-bedded dolomites with considerable clastic sediment and a minor constituent of

flat-pebble conglomerate. Walcott[1] places the lower boundary of the Upper Cambrian approximately in the middle of this lower series (Member o), at the base of a sandstone member. No fossils have been found in the 1,000 feet of beds (Nounan formation) next beneath that horizon, but the Bloomington formation, next below, carries a Middle Cambrian fauna.[2] As the shales of Member o in Montana and Wyoming have been assigned to the Middle Cambrian, they are possibly to be correlated with the green shales of the Bloomington formation.

Members 3 and 4 in northern Utah.—The main flat-pebble conglomerate series (Member 3) on Blacksmith Fork is 800 feet thick, and has yielded fossils at several horizons. These collections have established the Ordovician age of all but the lower 190 feet of the member, which is left by Walcott[3] in the Upper Cambrian. The Garden City formation in the Randolph quadrangle is described by Richardson[4] as containing flat-pebble conglomerate throughout its estimated 1,000 feet of thickness, but it may include a representative of Member 4 as well as of Member 3. Richardson's collections[5] are like those of the writer from Member 4 on Blacksmith Fork, and clearly indicate that this formation is of Beekmantown age, possibly ranging up into slightly later time.

Richardson[6] states that he has evidence of an unconformity between Cambrian and Ordovician, but this evidence is not yet published. Elsewhere in Utah no evidence has been cited of an interruption in sedimentation at this horizon, and it is certain, as indicated by the exact similarity between the latest Cambrian and the earliest Ordovician rocks, that if similar conditions were not continuous from the former period into the latter in this region they returned with very little modification after the interruption. The upper record succeeds the lower without the intervention of any clastic sediments.

[1] C. D. Walcott, "Cambrian Cordilleran Sections," *Smithsonian Misc. Coll.*, LIII (1910), 193.

[2] Walcott, *op. cit.*, pp. 194–95. [3] *Op. cit.*, p. 191.

[4] G. B. Richardson, "The Paleozoic Section in Northern Utah," *Amer. Jour. Sci.*, 4th Ser., XXXVI (1913), 406–15.

[5] *Op. cit.*, pp. 408–9. [6] *Op. cit.*, p. 408.

Correlation with the Pogonip group of Nevada.—The Pogonip group of the Eureka district of Nevada, called Lower Silurian by Hague[1] and Walcott,[2] probably includes equivalents of the Garden City formation and part or all of the St. Charles formation (Upper Cambrian, Blacksmith Fork). The upper part of the Pogonip group carries a fauna, considered by Walcott[3] to be of Chazyan age, which bears a notable resemblance to the faunas of the Garden City formation.

Member 3 in Wyoming and Montana.—In Wyoming the thin-bedded Upper Cambrian–Lower Ordovician(?) sequence, including flat-pebble conglomerate, is nowhere represented by more than 500 feet of strata, but its characters are typical of Member 3 wherever it is exposed. In southwestern Montana it forms the highest member of the Gallatin formation.

The faunas so far collected from this sequence in both Wyoming and Montana are very meager, a fact which has made its correlation a subject of dispute in various localities. In the Bighorn Range, Member 3 constitutes the uppermost part of the Deadwood formation, which is called by Darton[4] Middle Cambrian; but the only species Darton names as coming from the upper 600 feet of the formation (about 1,000 feet thick in all) is *Dicellomus politus*, which is associated in one locality[5] with fragments of a trilobite resembling *Ptychoparia oweni*. Some collections from the upper part of the Gallatin formation in western Wyoming, comprising three species of *Eoorthis* and some fragmentary trilobite remains, have been referred to the Upper Cambrian by paleontologists of the United States Geological Survey.[6] Member 3 probably is represented

[1] Arnold Hague, "Geology of the Eureka District, Nevada," *U.S. Geol. Survey, Monographs*, XX (1892).

[2] C. D. Walcott, "Paleontology of the Eureka District," *U.S. Geol. Survey, Monographs*, VIII (1884).

[3] *Op. cit.*, pp. 3–4.

[4] N. H. Darton, "Geology of the Bighorn Mountains," *U.S. Geol. Survey, Prof. Paper 51* (1906), p. 26.

[5] N. H. Darton, "Fish Remains in Ordovician Rocks in the Bighorn Mountains, Wyoming, with a Résumé of the Ordovician Geology of the Northwest," *Bull. Geol. Soc. Amer.*, XVII (1905), 551.

[6] Eliot Blackwelder, personal note. Cf. C. D. Walcott, "Cambrian Brachiopoda," *U.S. Geol. Survey, Monographs*, XXXI (1912), 233, Lot 302*e*.

in the Red Lion formation (250 feet thick) of the Philipsburg quadrangle, Montana, from which Kindle[1] has made some collections identified by Walcott[2] as Upper Cambrian.

The beds in question probably are equivalent to some part or parts of Member 3 of the Utah sequence, and it is therefore possible that they may include strata of Lower Ordovician age.

The Maxfield formation of the central Wasatch.—Hintze[3] has described a sequence of 481 feet of limestones and shales "disconformably overlying the Alta shale"[4] on the South Fork of Big Cottonwood Canyon, southeast of Salt Lake City, which he has named the Maxfield formation, and has tentatively assigned to the Ordovician. The Alta shale (150–200 feet thick), which rests on the basal Cambrian quartzite, carries a Lower Cambrian fauna near its base and a Middle Cambrian fauna at a higher horizon.[5] Disconformably above the Maxfield lies the Devonian Benson limestone.

No fossils have been found in the Maxfield formation. Its reference to the Ordovician was suggested by the "wormy" appearance of the chief limestone members of the formation, which Hintze likened to the Lowville ("Birdseye") limestone of New York, and by the occurrence at the top of the formation of 10 feet of shale alternating with typical flat-pebble ("edgewise") limestone conglomerate, which Hintze[6] noted had been described from Lower Ordovician strata elsewhere. Unfortunately for this correlation, conglomerate of that type is abundantly developed in northern Utah, not only in the Garden City (Beekmantown) formation, but in the St. Charles (Upper Cambrian) and Bloomington (Middle Cambrian) formations. The "wormy" appearance is to be seen in various members of each and all of the six Middle and Upper

[1] E. M. Kindle, "Fauna and Stratigraphy of the Jefferson Limestone in the Northern Rocky Mountain Region," *Bull. Amer. Pal.*, No. 20, 1908, pp. 10–11; also Emmons and Calkins, *op. cit.*, p. 63.

[2] C. D. Walcott, *op. cit. ult.*, p. 233, Lots 302*q*, 302*r*.

[3] F. F. Hintze, Jr., "A Contribution to the Geology of the Wasatch Mountains, Utah," *Annals New York Acad. Sci.*, XXIII (1913), 85–143.

[4] *Ibid.*, p. 105.

[5] C. D. Walcott, *U.S. Geol. Survey, Bull. No. 81*, 1891, p. 319.

[6] *Op. cit.*, p. 106.

Cambrian formations at Blacksmith Fork, but has not been noted in the Garden City formation. Amounts of shale comparable to that in the Maxfield (about 180 feet, all told) are present only in the Langston, Ute, and Bloomington formations at Blacksmith Fork.

Furthermore, flat-pebble conglomerate is abundant throughout the lower 600 feet (about half) of the Garden City formation at Blacksmith Fork, but has not been noted in the upper half of the formation there at all. The relation noted in the Maxfield formation, of 480 feet of interbedded shales and limestones with flat-pebble limestone conglomerate in the upper 10 feet only, could thus not be matched in the Garden City formation. A sequence almost precisely similar to that of the Maxfield formation does occur, however, in the Bloomington formation.

The Maxfield formation of the central Wasatch, therefore, is probably of Cambrian age, and bears a striking likeness to the Middle Cambrian Bloomington formation of the Bear River plateau, 75 miles farther north.

The close relation of the Canadian series to the Upper Cambrian series.—If the upper limit of the Cambrian system in northern Utah has been defined correctly, the changes which took place between Canadian (or Chazyan) and Trenton time in the Rocky Mountain–Great Basin paleogeographic province were more notable than those which occurred between Upper Cambrian and Canadian time in that region. The latest sediments assigned to the Upper Cambrian are of the same type as the Canadian deposits, whereas the sediments of Trenton age are very different from either of the former. The erosion preceding the beginning of Trenton sedimentation is known to have been extensive, whereas evidence of erosion between Upper Cambrian and Canadian time is reported from only one locality.

The physical evidence thus goes to show that the affinities of the Western Canadian are rather with the Cambrian than with the higher Ordovician.

Is the Ozarkian system represented here?—If the Ozarkian period of Ulrich is represented in the western province, it must be by some part of the Upper Cambrian–Lower Ordovician sequence above

described. In the absence of an adequate description of the fauna of the typical Ozarkian, it is difficult to make comparison therewith. The base of the Ordovician was placed by Walcott[1] at Blacksmith Fork at the first appearance of cephalopods. As determined by Richardson[2] in the Randolph quadrangle, the base of the Garden City formation there is marked by the appearance of several genera of coiled gastropods. The post-Cambrian, pre-Swan Peak (see below) series thus defined has a thickness on Blacksmith Fork of 1,272 feet, which is 68 per cent greater than the total thickness of the overlying Ordovician, including the Richmond. As above noted, Richardson describes a marked unconformity at the top of the Cambrian in the Randolph area. These faunal distinctions and this physical evidence may warrant the recognition of the series in question as a separate system; but there is no evidence yet at hand to suggest its subdivision into *two* systems, Ozarkian and Canadian. It is possible that the St. Charles formation includes a representative of the former.

Up to the present, however, the Ozarkian has not been recognized in the Rocky Mountains.

THE ORDOVICIAN QUARTZITES AND SANDSTONES

The Eureka and Swan Peak quartzite.—In eastern Nevada the unfossiliferous Eureka quartzite, ranging from 200 to 500 feet in thickness, lies in apparent conformity upon the Pogonip limestone. The upper surface of the Eureka quartzite is clearly an irregular erosion surface. It is overlain by the Lone Mountain limestone, which carries a Trenton fauna near its base.[3]

The Eureka quartzite corresponds closely in stratigraphic relations to the quartzite at Geneva[4] and to the Swan Peak[5] quartzite, both in northern Utah, which attain a similar thickness. Unconformity is evident above the Swan Peak quartzite in the Randolph quadrangle,[6] and farther south the post-Swan Peak erosion locally

[1] C. D. Walcott, "Cambrian Cordilleran Sections," *Smithsonian Misc. Coll.*, LIII (1910), 191.

[2] *Op. cit.*, pp. 408–9. [3] Hague, *op. cit.*, pp. 58–59.

[4] Eliot Blackwelder, "New Light on the Geology of the Wasatch Mountains, Utah," *Bull. Geol. Soc. Amer.*, XXI (1910), 526–27.

[5] Richardson, *op. cit.*, p. 408. [6] *Ibid.*

resulted in the complete removal of the quartzite, so that in the section exposed on Blacksmith Fork the succeeding dolomites of Trenton(?) age rest unconformably on the Garden City formation.

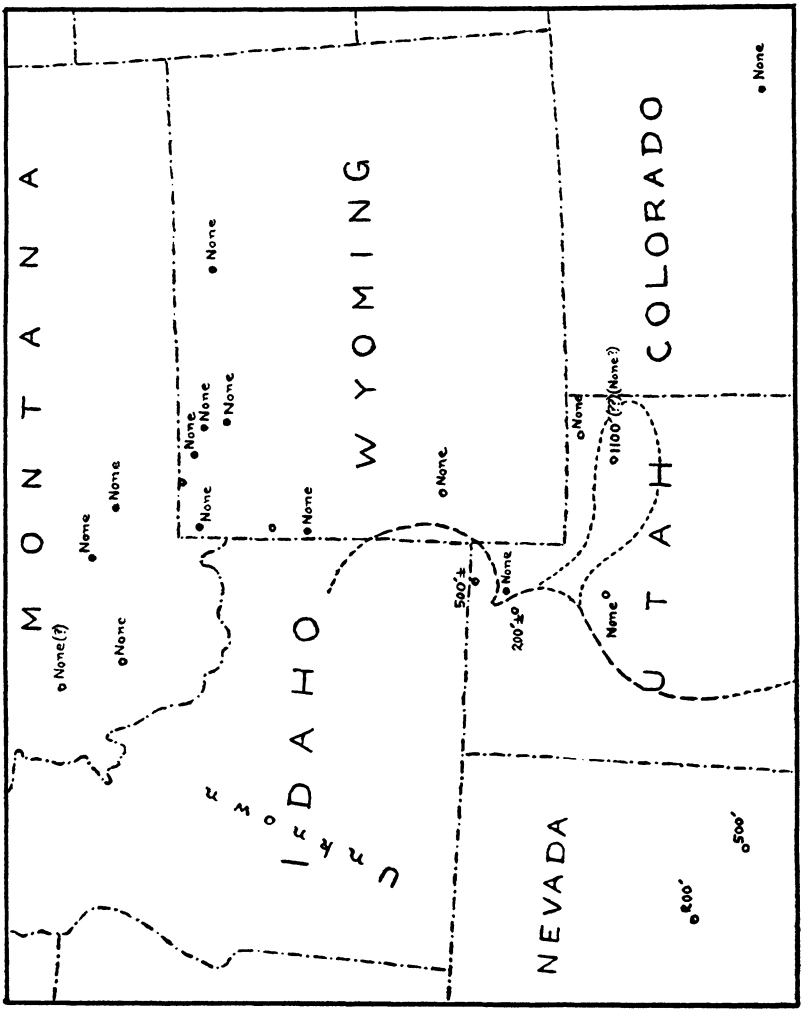

FIG. 7.—Map showing the extent and thickness of the Chazyan (?) quartzites

The Swan Peak quartzite contains a small fauna which has been referred tentatively to the Chazyan by Ulrich.[1] Four of the eight forms identified from the Swan Peak are found also in the similarly

[1] *Op. cit.*, p. 408.

meager fauna of the quartzite at Geneva.[1] There is no representative of these quartzites in the section described by Hintze[2] in Salt Lake County, Utah, 75 miles south of Blacksmith Fork.

The absence of the Swan Peak quartzite from the Blacksmith Fork section is especially notable in view of the fact that it occurs with a thickness of several hundred feet less than 20 miles to the northeast, in the Randolph area, and also less than 20 miles away in the opposite direction, near Geneva.

The "Ogden quartzite" in the Uinta Range.—In the south slope of the Uinta Range a quartzite attaining a maximum thickness of about 1,100 feet lies between the Mississippian system and the barren Lodore shales (Cambrian?). Weeks[3] correlated this formation with that which is called in this paper the Swan Peak quartzite, in the region east of Cache Valley, Utah; and he applied to both formations the same name, "Ogden quartzite." As no fossils have been found in the "Ogden quartzite" in the Uinta Range, the correlation rests on an insecure basis.

No representative of this quartzite was noted on the north flank of the Uinta Range.

The sandstone at the base of the Bighorn formation.—The Trenton dolomites in Wyoming for the most part lie directly on the flat-pebble conglomerate series, but locally they are accompanied by a thin basal sandstone carrying a late Black River or early Trenton fauna, including fish remains.[4] This sandstone is correlated with the fish-bearing Harding sandstone of Colorado,[5] which likewise is overlain by dolomites of Trenton age. It is probable, as has usually been considered, that this sandstone member represents an introductory stage of the Trenton submergence rather than that it is a deposit of an earlier submergence, separated by an epoch of erosion from the Trenton proper, as is the case with the Swan Peak and Eureka quartzites. The faunal lists from the Swan

[1] Blackwelder, *loc. cit. uls.* [2] *Op. cit.*

[3] F. B. Weeks, "Stratigraphy and Structure of the Uinta Range," *Bull. Geol. Soc. Amer.*, XVIII (1907), 436–37, 441.

[4] N. H. Darton, *op. cit.* (1905), p. 551; and Bald Mountain–Dayton Folio, Wyoming, *Geol. Atlas U.S.*, Folio No. 141 (1906), p. 4.

[5] N. H. Darton, *op. cit.* (1905), p. 552; and Folio 141, p. 4.

Peak quartzite[1] and the quartzite at Geneva[2] include no species, and only two genera (*Orthis* and *Endoceras*) in common with the published lists of fossils from the Harding sandstone[3] and the basal Bighorn sandstone.[4]

THE MIDDLE AND UPPER ORDOVICIAN DOLOMITES

Extent of the Bighorn dolomite.—The Bighorn dolomite was named by Darton[5] from its characteristic exposures on both flanks of the Bighorn Range in northern Wyoming, and by him was correlated with the Whitewood limestone of the Black Hills and with the Fremont limestone of the Front Range of Colorado.[6] The same author later recognized the Bighorn dolomite in the Owl Creek[7] and Wind River[8] ranges of Wyoming. Fisher[9] briefly described its occurrence in Cedar and Rattlesnake Mountains, west of Cody, Wyoming. Blackwelder[10] has identified it in the Gros Ventre and Teton ranges, farther west.

The Bighorn dolomite in Montana.—Both Darton[11] and Fisher[12] prophesied that the Bighorn dolomite would be found to be included in the "Jefferson limestone" of Hague, and the truth of this

[1] Richardson, *op. cit.*, p. 410. [2] Blackwelder, *op. cit.* (1910), p. 527.

[3] N. H. Darton, "Fish Remains in Ordovician Rocks in the Bighorn Mountains, Wyoming, with a Résumé of the Ordovician Geology of the Northwest," *Bull. Geol. Soc. Amer.*, XVII (1905), 563.

[4] *Ibid.*, pp. 554–56, footnote.

[5] N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range," *Bull. Geol. Soc. Amer.*, XV (1904), 379–448.

[6] N. H. Darton, "Description of the Bald Mountain and Dayton Quadrangles," *Geol. Atlas U.S.*, Folio 141 (1906), p. 4.

[7] N. H. Darton, "Geology of the Owl Creek Mountains," Fifty-ninth Congress, 1st session, Senate Document No. 219 (1906), p. 15.

[8] N. H. Darton, "The Paleozoic and Mesozoic of Central Wyoming," *Bull. Geol. Soc. Amer.*, XIX (1908), 403–74.

[9] C. A. Fisher, "Geology and Water Resources of the Bighorn Basin, Wyoming," *U.S. Geol. Survey, Prof. Paper 53* (1908), p. 12.

[10] Eliot Blackwelder, unpublished manuscripts, *U.S. Geol. Survey.*

[11] N. H. Darton, "Fish Remains in Ordovician Rocks in the Bighorn Mountains, Wyoming, with a Résumé of the Ordovician Geology of the Northwest," *Bull. Geol. Soc. Amer.*, XVII (1905), 554.

[12] *Op. cit.*

prophecy has now been demonstrated by the writer's work. The Bighorn dolomite is characteristically developed throughout the length of the Absaroka Range, and has yielded Ordovician fossils

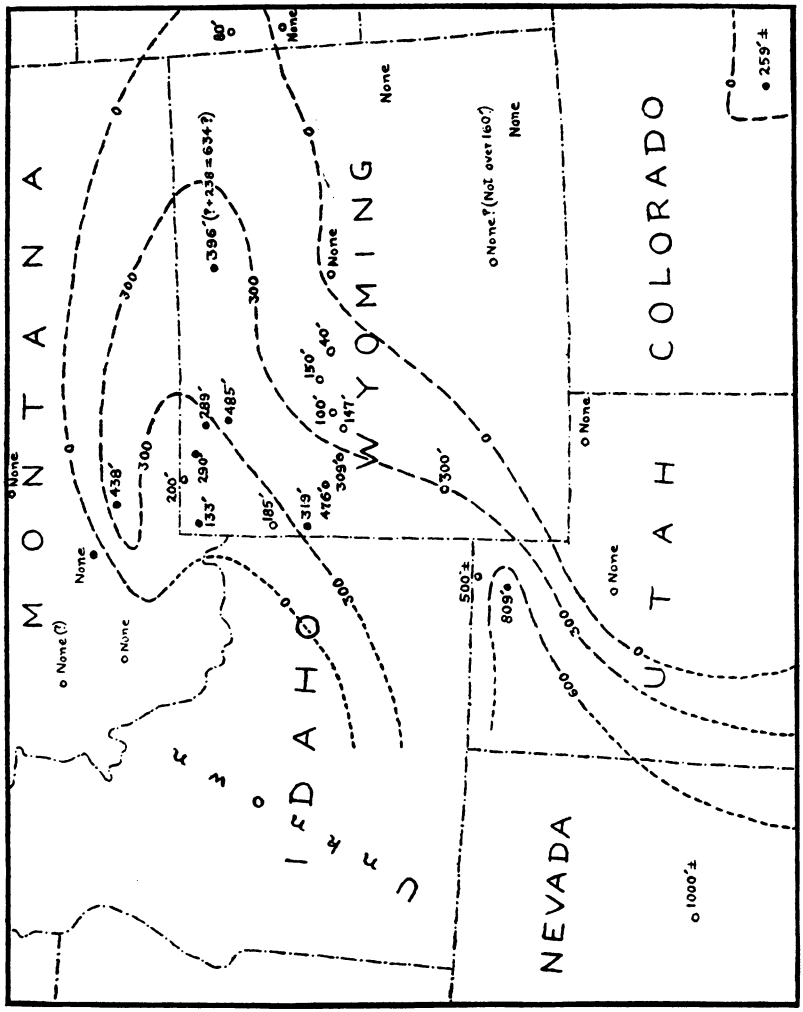

FIG. 8.—Map showing the extent and thickness of the Bighorn dolomite (Middle and Upper Ordovician) and correlated formations.

in the Crandall (Wyoming) and Livingston (Montana) quadrangles. It is a remarkable fact that, although this formation is 438 feet thick in Livingston Peak, it has no known continuation north of that point, nor west beyond the Gallatin Range.

Members 2–4.—There can be little doubt as to the validity of most of the correlations of Trenton strata shown in the preceding table and diagrams, except in Utah and Nevada. The main massive member (No. 4) of the Lower Bighorn, with its accompanying basal weaker strata (Members 2 and 3) and its cap of smooth, nearly chalky, dolomite, constitutes a highly characteristic and almost unique series. Furthermore, Member 2 is fossiliferous, and Member 4 is sparingly so in nearly all localities.

The upper half of the massive member in the Blacksmith Fork section, which the writer has called the Lower Fish Haven dolomite, is similar in all essential respects to the massive Trenton member of the typical Bighorn. It is marked off from the Richmond above by a conglomerate, and disconformity at its base is sufficiently indicated by the absence of the (Chazyan?) quartzite which intervenes at that horizon elsewhere in northern Utah. This lower Fish Haven dolomite carries *Halysites*, which is not known from rocks older than Mohawkian.

The lower part of the Lone Mountain limestone, which unconformably overlies the Eureka quartzite in western Nevada, carries a fauna assigned by Walcott[1] to the Trenton. Ulrich[2] has voiced the opinion that part of the Lone Mountain limestone is older than the Bighorn dolomite; but it is probable that the former formation contains a representative of the Trenton series.

Members 5–7; the Leigh formation.—Members 5–7 of the Middle and Upper Ordovician series constitute a distinct and very widely developed unit. In the Goose Creek Ridge section there is little ground for differentiating these three from each other; but the lowest Richmond fauna occurs in the beds there marked as Member 6. In the Crandall Creek and Dead Indian Creek sections there is a conspicuous surface of disconformity, with a basal breccia, at the base of Member 6. As this is the only disconformity for which physical evidence has so far been noted anywhere within the limits of the Bighorn formation, and as it coincides (by lithologic correla-

[1] Arnold Hague, *op. cit.*, pp. 61–62, 196–97; also appendix by C. D. Walcott, pp. 324–25.

[2] Cf. Bailey Willis, "Index to the Stratigraphy of North America," *U.S. Geol. Survey, Prof. Paper 71* (1912), p. 169.

tion of beds both above and below) with the base of the known Richmond part of the Bighorn in the type locality, it probably represents the hiatus which was inferred by Darton between the Trenton and Richmond members of the Bighorn.

In the Teton Range, there is likewise an unconformity at the base of Member 6. Blackwelder[1] proposes the recognition of Members 6 and 7 in that region, and of corresponding strata in the Gros Ventre Range, as a distinct formation, to be called the *Leigh*, from its typical development on Leigh Creek, in the Teton Range. In view of the fact that this group of strata, in its type locality, is bounded both above and below by unconformity, and is lithologically quite distinct from the underlying massive member (Member 5 is not present in the Teton River section), its recognition as a separate formation seems justified. In the Absaroka Range the corresponding beds differ little in character from the upper part of the Trenton series (Member 5), but are marked off from it by unconformity, as just described.

Between Members 4 and 8 of the Livingston Peak section, light-colored dolomites of the Leigh type occur interbedded with darker, gray-brown, more coarsely crystalline dolomites. In the Blacksmith Fork section there is an interbedding of light and dark strata through a thickness of 130 feet above the conglomeratic horizon, which is taken as the probable base of the Richmond series. Above this sequence there is an 8-foot stratum corresponding closely to the typical Leigh in character, and directly underlying the main massive part of the Fish Haven, which is correlated with Member 8. The first sediments deposited after the pre-Richmond emergence seem to be more variable in character from place to place than are the strata above them, or the members of the Trenton series.

Members 8 and 9.—Member 8 is in some places, in lithologic characters, essentially similar to Member 4, but is in no case quite so thick as the latter. On Goose Creek Ridge there are only two 12-foot massive beds of this type, themselves separated by 20 feet of less resistant dolomites, between the typical Leigh (Members 6 and 7) below and the main fossiliferous, thin-bedded part of the

[1] Eliot Blackwelder, personal note.

Richmond series above. It is possible that the much thicker massive dolomite characterizing the Upper Bighorn in the Absaroka Range is equivalent to a part of this thin-bedded series (called Member 9), as well as to the underlying more massive beds. On Blacksmith Fork, Member 8 forms the main body of the Upper Fish Haven dolomite. In common with several other parts of the Ordovician system, it is somewhat darker in color there than in Wyoming.

The highly fossiliferous, thin-bedded dolomites (Member 9) of the Upper Bighorn in the Bighorn Range unfortunately are not typically developed elsewhere.

There is no representative of the Bighorn in Hintze's[1] section in the central Wasatch, nor in the Uinta Range.[2]

[1] F. F. Hintze, Jr., *op. cit.*

[2] F. B. Weeks, *op. cit.*